WILDLIFE RESPONSE TO HABITAT RESTORATION IN FORT FUNSTON, GOLDEN GATE NATIONAL RECREATION AREA, CALIFORNIA

Final Report

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ABSTRACT

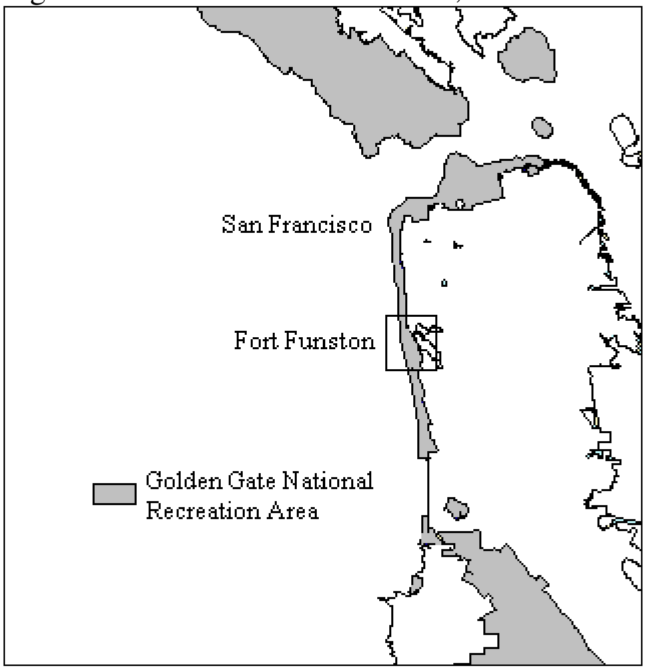
Dune scrub communities have been altered by urbanization, human disturbance, and the introduction of non-native species. Small fragments of native dune vegetation may conserve locally threatened plant and animal species within urban landscapes. The effect of restoring natural dune vegetation on wildlife abundance and diversity was measured at Fort Funston, Golden Gate National Recreation Area, San Francisco, California in 2001 and 2002. Data were collected on wildlife and vegetation in four habitat areas, including a 9.3-hectare restored area where visitor use was restricted, two unrestored areas approximately 4-hectares in size where visitor use was restricted, and a 6.8-hectare area where visitor use was unrestricted. A combination of variable circular plot point counts and area searches were used to detect avian species. Terrestrial wildlife was detected using pitfall trap arrays, cover boards and sooted track plates. Random plot sampling was used to characterize vegetation. The species diversity of birds and terrestrial vertebrates was significantly higher in the restored area compared to the unrestricted/unrestored area. In addition, terrestrial vertebrate abundance was significantly higher in the restricted/restored area compared to the unrestored area. Results from this study suggest a positive wildlife response to the active restoration of native vegetation within the study area.

Keywords: habitat restoration, dune-scrub community, non-native species, anthropogenic impacts, wildlife response

INTRODUCTION

Restoration of disturbed habitat has become common practice in natural areas, including the Golden Gate National Recreation Area. The direct benefits to the diversity and abundance of native vegetation are clear. However, the benefits of these restoration efforts to wildlife species are not as apparent. With this study, we measured wildlife diversity and abundance associated with habitat restoration on a dune scrub community site in San Francisco, California (Figure X).

Figure 1. Location of Fort Funston, Golden Gate National Recreation Area.



Fragmented habitats that exist in urban areas provide a last refuge for many locally threatened plant and animal species otherwise absent from the surrounding urban matrix (Morrison et al. 1994). These areas also improve connectivity between larger, more contiguous habitats in nearby parks and open space reserves. Restoration of these small patches is critical to the conservation of biodiversity in urban landscapes (Marzluff and Ewing 2001). It is also generally assumed that habitat restoration improves conditions for wildlife, but this assumption is rarely tested (Block et al. 2001).

Dune scrub communities, which are prone to human disturbance and characterized by openings in the vegetation, are particularly susceptible to non-native plant introduction, especially in urban settings (Pickart and Sawyer 1998). Non-native species introduction can have a dramatic impact on native vegetation and associated wildlife species by altering community composition and reducing diversity of native plants (Alvarez and Cushman 1997). The original San Francisco dune system was species rich and contained a wide spectrum of dune forms and successional stages (Gaar 1999, Cooper 1967, Howell et al. 1958, Kaufeldt 1954, Ramaley 1918, Brandegee 1892, Bolander 1863).

Since the 1870s, the topography, stability and soils of San Francisco dune remnants have been highly modified by the residual effects of past introductions of dune stabilizing vegetation. Non-native European beachgrass (*Ammophila arenaria*) was first planted in the 1870s to stabilize otherwise mobile dunes, and has created steep, hummocky topography. Non-native iceplant (*Carpobrotus edulis*) was planted to stabilize both mobile and relatively stable dunes. Non-native trees and shrubs such as Monterey cypress (*Cupressus macrocarpa)*, blue gum (*Eucalyptus globulus*), and wattle (*Acacia* spp.) were also planted to act as strong baffles to dune-forming winds.

San Francisco dune remnants have also been modified by human-induced impacts such as urbanization and recreational use. Natural dune vegetation plays a role in trapping windblown sand and in forming barriers that protect hind-dune areas from inundation, salt spray and sand blast. Restricting visitor use on dune and beach areas for the purpose of precluding human and domestic animal impacts may be an effective tool for protection and enhancement of coastal dune species (U.S. Fish and Wildlife Service 2001, Grove et al. 2000, Lafferty 2000, Baker 1999). Studies have shown that fencing of dune habitats directly contributes to the protection and recovery of federally and state-listed wildlife species such as the California Least Tern (*Sterna antillarum* ssp. *browni*) and Western Snowy Plover (*Charadrius alexandrinus* ssp. *nivosus*) (Lafferty 2000, Hatch 1996, Page 1990, Saul 1982, Massey 1972, Craig 1971). Previous studies indicate that a combination of restoration efforts, such as active restoration and fence exclosures, may be a more effective approach for broader efforts to increase overall species diversity and abundance (Unocal 2002, Alvarez and Cushman 1997).

Study Objectives

In this study, we analyzed the effect of active habitat restoration and restricted use on wildlife abundance and diversity in a residual dune scrub community at Fort Funston, San Francisco. The specific goals of this project were to (1) establish monitoring plots to collect baseline data on wildlife and vegetation abundance and diversity, and (2) evaluate the effect of dune habitat restoration, including native planting and fencing techniques using measures of wildlife and vegetation abundance and diversity.

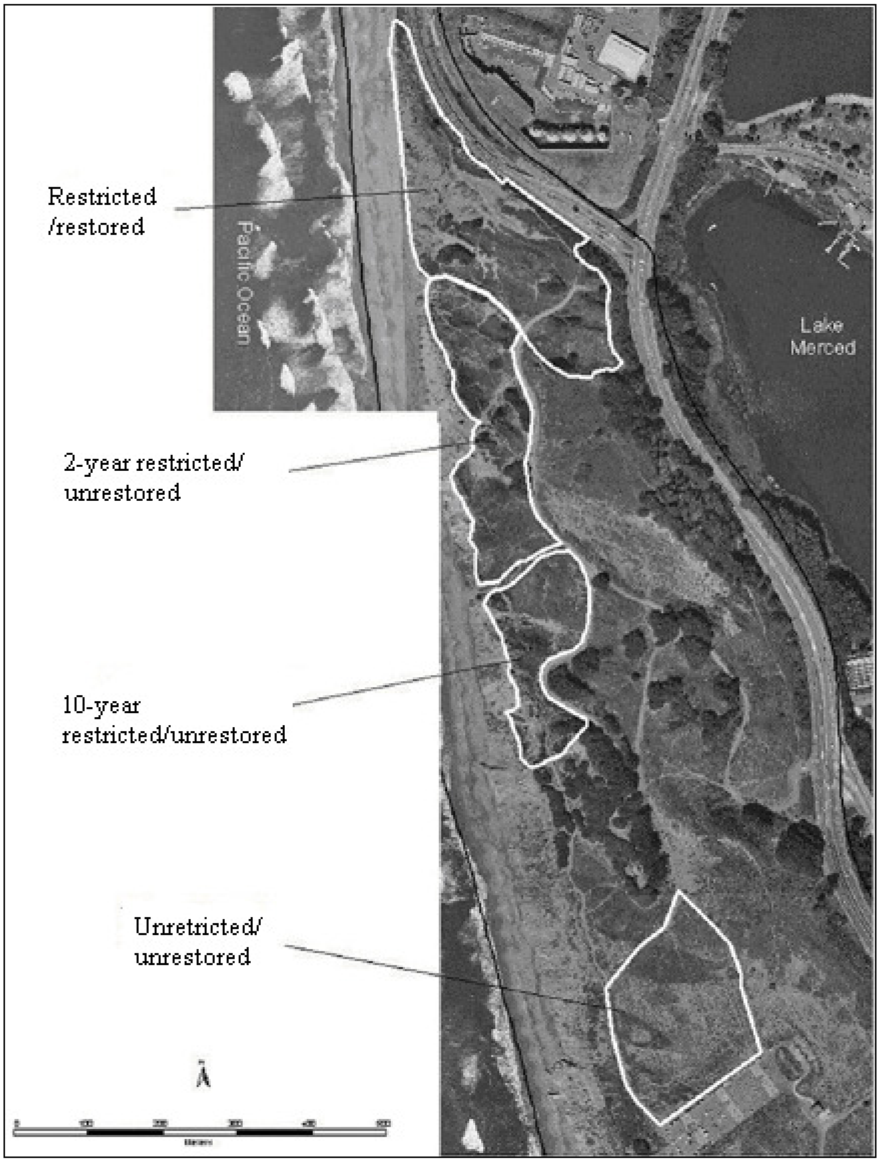
METHODS

We conducted comparative surveys for birds, terrestrial vertebrates, and vegetation in the following four habitat areas within Fort Funston, Golden Gate National Recreation Area, California (Table 1): (1) Restricted/restored: 9.3-hectare restricted habitat protection closure with restored native dune vegetation, (2) 10-year restricted/unrestored: 4-hectare restricted habitat protection closure with non-native dune vegetation, (3) 2-year restricted/unrestored: 4.8-hectare restricted habitat protection closure with non-native dune vegetation, and (4) Unrestricted/unrestored: 6.8-hectare parcel with no habitat protection closure and non-native dune vegetation (Figure 2).

Table 1. Habitat areas in Fort Funston, GGNRA

Habitat Area	**Hectares**	**Fenced**	**Restored**
Restricted/restored	9.3	Yes (1991)	Yes (1992-1994)
10-year restricted/unrestored	4	Yes (1991)	No
2-year restricted/unrestored	4.8	Yes (1999)	No
Unrestricted/unrestored	6.8	No	No

Figure 2. Location of habitat restoration sites in Fort Funston, Golden Gate National Recreation Area



Study Area

Fort Funston encompasses approximately 93 hectares along the coast of the northern San Francisco peninsula, in California, and is part of the Golden Gate National Recreation Area. It is located south of Ocean Beach and north of Pacifica, and it is flanked to the east by both John Muir Drive and Skyline Boulevard and to the west by the Pacific Ocean.

Fort Funston is the largest of several significant remnants of the San Francisco dune complex that was once the 4^{th} largest dune system in the state, covering approximately 36 square kilometers. More than 95% of the original dune system has been drastically altered by urbanization and development. Historic accounts documenting San Francisco's native dune species can be used to reconstruct the likely historic flora of Fort Funston. Surveys of Fort Funston confirm that its remnant flora is clearly allied with other dune systems (Howell et al. 1958).

During the 1930s, the U.S. Army built a system of coastal defense batteries that changed the dune topography east of the bluffs and removed much of the native plant community. Following construction, the Army planted a non-native species, iceplant (*Carpobrotus edulis*), in an attempt to stabilize open sand around the batteries. By the mid-1960s, extensive areas of Fort Funston were covered with invasive, exotic plants. In 1972 Fort Funston was closed as a military base and transferred to the National Park Service to become part of Golden Gate National Recreation Area.

Approximately three-quarters of a million visitors now visit Fort Funston annually, further impacting native plant and wildlife communities. While native dune vegetation is adapted to a harsh environment characterized by abrading winds, desiccating soils, and low nutrient conditions, repeated human use of trails has adverse impacts on dune vegetation (Edwards 1978). In addition, heavy off-leash dog use increases deterioration of native dune communities. Intensive trampling of vegetation by dogs weakens vegetation in a similar manner as trampling by humans (Sime 1999).

The National Park Service implemented a dune restoration project in 1991 to protect critical habitat for the state-threatened bank swallow (*Riparia riparia*), to restore native dune vegetation, and to reduce human-induced impacts to the coastal bluffs and dunes. This restoration project involved the removal of virtually all non-native plants from a 9.3-hectare restricted exclosure. The non-native vegetation, which was dominated by iceplant, was removed either by hand in some or with a bulldozer. Following the removal of non-native vegetation, native dune-scrub vegetation was initially planted between 1992 and 1994. Native vegetation used for the restoration process was grown on site in the native plant nursery from local seed sources. Maintenance, including the removal of non-native species and planting of more native species, has continued following the initial restoration up until the time of this study. The fenced exclosure consists of wooden posts and cable, as well as a line of brush that was piled up along the fence, discouraging the majority of visitors and dogs. This 9.3-hectare site will be referred to as "Restricted/restored."

In addition to the restricted/restored site, land managers restricted use on a 4-hectare area in 1991 "10-year restricted/unrestored" and a 4.8-hectare area in 1999 "2-year restricted/unrestored" to improve public safety and restore additional native dune vegetation. The 10-year restricted exclosure consists of wooden posts and cable, while the 2-year restricted exclosure consists of wooden posts, cable, and wire mesh fixed to the inside of the cable. Foot traffic and use by pets was prohibited within these restricted areas. The fencing itself was designed to discourage foot traffic, but it did not present a physical barrier significant enough to eliminate all foot traffic or use by dogs.

The remaining 68 hectares of the park remained open and accessible to park visitors and their pets. Some active restoration occurred within this area, specifically around the native plant nursery and the ranger station. Visitors did not heavily use this area, and off leash pet use was discouraged by the presence of park law enforcement officials. This area was not included in this research project. A 6.8-hectare area that did receive heavy visitor use, including off leash pets was included in the research project. This area is referred to as "unrestricted/unrestored" throughout this report.

These habitat areas were not designed with this research project in mind. Therefore this study has a post-hoc design with limited scope. The gathering of data regarding wildlife response to habitat restoration from multiple sites in the future will broaden the data set giving greater validity to the results.

Wildlife Sampling

A variety of survey techniques were utilized to detect birds, amphibians, reptiles, and mammals during the rainy season (November through April) and the dry season (May through October).

Variable Circular Plots: Bird survey plot locations were selected along a random line transect, running north-south through all four habitat areas. Plots were placed a minimum of 250 meters apart and a minimum of 50 meters from all habitat edges (i.e. trails, fence-lines, vegetative boundaries) (Ralph et al. 1993). Two survey plots were located in both the unrestricted/unrestored and restricted/restored habitat types and one study plot was located in both the 10-year restricted and 2-year restricted, unrestored habitat types. UTM coordinates, based on World Geodetic System (WGS) 84 datum, were obtained using a hand-held GPS unit, and all plots were mapped on a USGS 7.5' quad map (Appendix 1).

During the breeding season (May-July), birds were surveyed using the variable circular plot point count technique to determine relative abundance and species composition in all four habitat areas (Ralph et al. 1993). Plots were surveyed for 4 days with a minimum 20-day period between visits. All birds detected by sight or by sound were recorded during a 5-minute period between sunrise and 10 am. Distance between the observer and the individual detection was estimated in 25-meter increments (0-25 meters, 26-50 meters). Detection was recorded during two time periods: 0-3 minutes and 3-5 minutes. In this way, data can be compared to regional data from PRBO Conservation Science and long-term trend data from the Breeding Bird Survey (Sauer et al. 2001). Birds detected greater than 50 meters from the observer or flying over the study area were recorded, but these data were not included in the statistical analysis. Weather conditions were recorded at the end of the five-minute survey. Surveys were not conducted during periods of high winds (15-20 knots) or rain.

Area Search Plots: The four habitat areas were divided into 2.5-hectare sections to maximize the number of areas searched in each habitat (Ralph et al. 1993). This enabled us to locate two area search plots in both the unrestricted/unrestored and restricted/restored habitat areas and one area search plot in both the 10-year restricted and 2-year restricted, unrestored habitat types. All areas were located at least 25 meters from all habitat edges. All areas were mapped using GIS software. Site descriptions were compiled regarding area boundaries (Appendix 2).

During the non-breeding season, birds were surveyed using area searches to better detect non-vocal individuals (Ralph et al. 1993). Each 2.5-hectare area was searched for a 10-minute period between sunrise and 10 am. All individuals detected by sight or by sound within the area were recorded. Weather conditions were recorded at the end of the 10-minute survey. Surveys were not conducted during periods of high winds (15-20 knots) or rain.

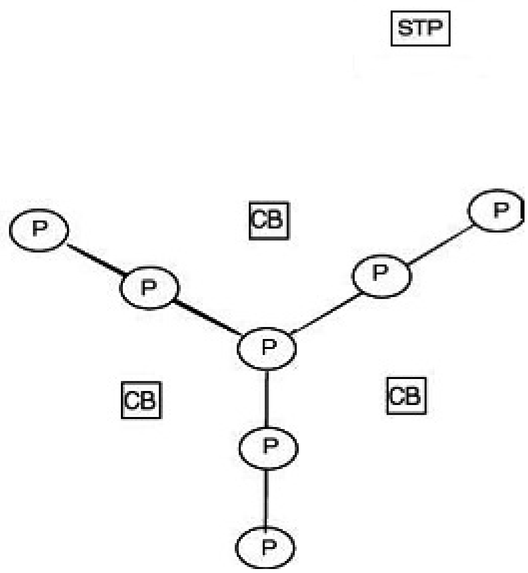


Figure 3. Diagram of terrestrial vertebrate sampling techniques, including pitfall traps (P), cover boards (CB), and sooted track plates (STP). Lines connecting pitfall traps represent drift fencing.

Pitfall Arrays: Pitfall arrays were utilized to determine species composition and relative abundance of amphibians, reptiles, and small mammals in all four habitat areas. Arrays were comprised of seven pitfall traps and three drift-fence arms extending 15 meters from the center point (Corn and Bury 1990). Pitfall traps were constructed using five gallon buckets placed flush with the ground, covered with 30 x 30 x 0.7 centimeter plywood board raised 5 centimeters above the bucket to provide cover (Bury and Raphael 1983, Davis 1982). Inside the buckets, moist sponges were provided to prevent desiccation of amphibians, cotton was provided to prevent hypothermia of mammals, and 4-centimeter diameter insulated PVC pipe was provided to protect animals from the elements and from predators. Drift-fencing was constructed from 25.4-centimeter aluminum sheeting, secured in the ground by 61-centimeter wooden stakes. Arrays were oriented with one pitfall trap at the center point and with three arms extending 15 meters separated by 120^{o}. Additional pitfall traps were located at 7.5 meters and 15 meters along each arm (Figure 3). Traps were checked each morning during two 10-day trapping periods. All captured mammals were marked by clipping fur in a unique combination of locations to use mark-recapture techniques for estimating relative abundance. Morphological measurements, age and sex were recorded whenever possible for all captured individuals.

Two pitfall trap arrays were randomly located in each of the four habitat areas, using a compass to assign a random bearing and a stopwatch to assign a random distance. Array center buckets were placed at least 25 meters from all habitat edges. Array arm orientations were determined using a random compass reading, and subsequent arms were placed at a 120° angle. UTM (WGS 84) coordinates were acquired for the center of the array using a hand-held GPS unit, and arrays were mapped on a USGS 7.5’ quad map (Appendix 3).

Cover Boards: Cover boards, extra plywood pitfall lids, were placed between each array arm, 5 meters from the center bucket to provide artificial cover to detect additional amphibians and reptiles (DeGraff and Yamasaki 1992, Grant et al. 1992). Cover boards were checked every other day during the two 10-day trapping periods.

Sooted Track Plates: Mid-sized mammals were detected using sooted track plates baited with punctured cat food cans left out for a 10-day sampling period (Barrett 1983). Track stations consisted of two 40 x 80 centimeter aluminum sheets placed side-by-side to form an 80 x 80 centimeter square. One track station was placed 20 meters away from the pitfall trap array at a random orientation (Figure 1). Track stations were checked daily and were replaced when damaged by use or by fog and rain. An experienced biologist, familiar with sooted track plate detections, identified tracks.

Incidental Observations: All incidental wildlife observations were recorded as observers walked to and from study plots during all survey visits. Although the constant effort methods reported above are preferred, failure to record species on the way to and from study plots could potentially underestimate species present in the four habitat areas.

Dog Point Count Surveys: During the avian variable circular plot point counts, dogs were counted using a similar protocol. All dogs seen within 50 meters of the observer during avian point counts were recorded. All dog-wildlife interactions witnessed by researchers during vertebrate sampling periods were also recorded.

Vegetation Sampling

Vegetation sample plots were randomly located on an aerial photograph of Fort Funston using Arc View 3.2a (ESRI, Redlands, CA). Thirty vegetation plots were located in each of the four habitat areas. All plots were mapped using a hand-held GPS (Appendix 4). Sampling of vegetation occurred between April and June 2002 using 2 x 3 meter rectangular plots. In each plot, the following data were recorded: the occurrence of all species, the total percent vegetation cover, and the percent cover for each species. Data were used to determine the species richness and percent cover of annual plants, non-native and native species.

Statistical Analysis

Poisson regression analysis was used to determine differences in vertebrate species abundance and diversity in the four habitat types. Vertebrate data, including species richness and numbers of individuals, were analyzed in two groups: (1) birds and (2) amphibians, reptiles, and mammals. Since the vertebrate data consisted of relatively low counts with frequent counts of zero, the data were analyzed using a model that assumes an over dispersed Poisson distribution instead of a normal distribution (McCullagh and Nelder 1989). Interaction effects and treatment and seasonal main effects were analyzed for mammals, amphibians and reptiles. Treatment main effects were tested only for birds due to the lack of comparable, multiple-season data. Due to an insufficient sample size, bird data acquired by area search methods were not analyzed.

Treatment and seasonal effects were assessed using likelihood ratio chi-square tests. Differences between pairs of treatments were also assessed using the approach of Fisher's Least Significant Difference (likelihood ratio chi-square tests). Vegetation data were analyzed to determine the species richness and percent cover of non-native and native species. Variations of vegetation measures between all treatments were tested with ANOVA. In all cases a P-value of less than 0.05 was considered significant. Statistics were conducted using SAS statistical software (SAS 1999).

RESULTS

Wildlife Analysis

Variable circular plots: Four point count surveys were conducted at six bird plot locations in May, June and July 2001 and May 2002. Twenty-seven species were detected during the breeding season, including Great Blue Heron, Double-crested Cormorant, Brown Pelican, Mourning Dove, Rock Dove, Northern Harrier, Cooper’s Hawk, Anna’s Hummingbird, Allen’s Hummingbird, American Crow, Common Raven, European Starling, Brown-headed Cowbird, Brewer’s Blackbird, Red-winged Blackbird, Western Meadowlark, Purple Finch, House Finch, American Goldfinch, Pine Siskin, White-crowned Sparrow, Bank Swallow, Barn Swallow, Bewick’s Wren, Chestnut-backed Chickadee, Bushtit, and American Robin. These detections include all species seen or heard during the surveys, including those species detected greater than 50 meters from the survey location or flying over the survey location.

No significant difference was detected between the numbers of individual birds in the four habitat areas (X^2=5.75, df=3, p=0.12). An average of 7.25 ± 1.64 individuals was detected in the restricted/restored area, 2.75 ± 1.43 individuals in the 10-year restricted/unrestored area, 8.0 ± 2.44 individuals in the 2-year restricted/unrestored area, and 4.25 ± 1.26 individuals in the unrestricted/unrestored area.

A higher number of avian species was detected in the restricted/restored area compared to the unrestricted/unrestored area (X^2=8.96, df=1, p=0.0028; Figure 4). An average of 4.38 ± 0.79 species was detected in the restricted/restored area, 2.5 ± 0.84 species in the 10-year restricted/unrestored area, 3.0 ± 0.93 species in the 2-year restricted/unrestored area, and 1.5 ± 0.46 species in the unrestricted/unrestored area. There was no difference detected between the restricted and unrestricted, unrestored sites (Figure 2).

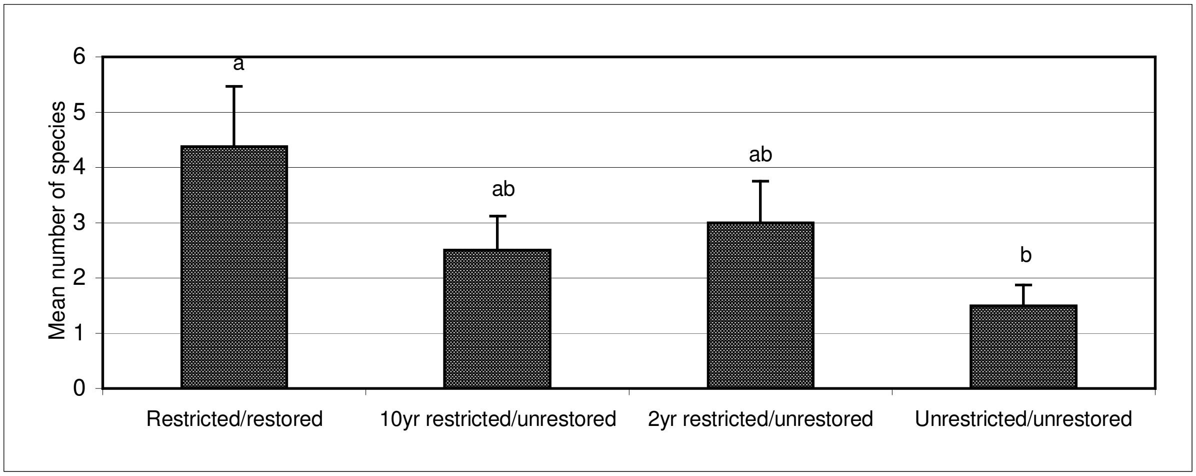


Figure 4. Avian species richness (mean number of species ± SE) in four habitats areas; $p < 0.01$. Treatments sharing the same lower-case letter were not statistically significantly different.

Avian species composition differed between the unrestricted/unrestored area compared to the restricted/restored area. Rock Dove and Barn Swallow were only detected in the unrestricted/unrestored area, while Mourning Dove, Bewick's Wren, Cooper's hawk, and Bushtit were only detected in the restricted/restored area. The Brown-headed Cowbird and American Goldfinch were detected in the restricted/restored area but were not detected in the unrestricted/unrestored area. The House Finch, White-crowned Sparrow, and American Robin were ubiquitous in all habitat areas.

Point Count plots: One area search was conducted on six plots during the non-breeding season in January 2002. Fifteen species were detected (Table 2). Over 85% of the species detected within the boundaries of the area search plots was detected in the restricted/restored habitat area. Only 14% of the species was detected in the unrestricted/unrestored and 10-year restricted/unrestored habitat areas. 57% of the species was detected in the 2-year restricted/unrestored habitat area. Statistical analyses were not conducted for these data, as the sample size was too small.

Table 2. Species present (+) within 50 m of point count plot locations during the breeding season.

Species	Restricted/ restored	10-yr restricted/ unrestored	2-yr restricted/unrestored	Unrestricted/ unrestored
Cooper's Hawk	+			
Mourning Dove	+			
Rock Dove				+
Anna's Hummingbird	+		+	+
Common Raven			+	
Barn Swallow				+
Bushtit	+			
Bewick's Wren	+			
American Robin	+	+	+	+
European Starling		+		
White-crowned Sparrow	+	+	+	
Brown-headed Cowbird	+	+	+	+
Brewer's Blackbird	+		+	+
House Finch	+	+	+	
American Goldfinch	+	+		+

During the non-breeding season, 14 individuals were detected in the restricted/restored area, 5 individuals were detected in the 10-year restricted/unrestored area, 11 individuals were detected in the 2-year restricted/unrestored area, and 16 individuals were detected in the unrestricted/unrestored area.

Table 3. Species present (+) within 2.5 ha area search plot boundaries counted for 10-minutes during the non-breeding season.

Species	Restricted/ restored	10-yr restricted/ unrestored	2-yr restricted/unrestored	Unrestricted/ unrestored
Mourning Dove	+		+	
Anna's Hummingbird	+			
Black Phoebe	+		+	
White-crowned Sparrow	+	+	+	
Song Sparrow	+		+	
Brewer's Blackbird				+
House Finch	+			

Pitfall trap arrays: 10-day trapping periods were conducted using pitfall trap arrays: one in February and May 2002. Nine species were detected using pitfall trap arrays, including two amphibian species, two reptile species, and five mammal species (Table 4). In addition, one species was identified using cover boards, one species was identified using sooted-track plates, and two species were detected using incidental wildlife observations made during bird point counts, area searches, and pitfall trap array sampling periods (Table 5).

Table 4. Amphibian, reptile and mammal species composition in four habitat areas. Numbers represent (1) the percent of buckets in which the species was present and (2) the number of individuals (in parenthesis).

Common Name	Scientific Name	Restricted/ restored	10-yr restricted/ unrestored	2-yr restricted/ unrestored	Unrestricted/ unrestored
California slender salamander	*Batrachoseps attenuatus*	2.14(3)	0.71(1)	0	0
California newt	*Taricha torosa*	0.71(1)	0	0	0
Northern alligator lizard	*Elgaria coerulea*	2.86(4)	0.71(1)	0	0
Southern alligator lizard	*Elgaria multicarinata*	4.28(6)	1.43(2)	0	1.43(2)
Botta's pocket gopher	*Thomomys bottae*	1.43(2)	2.86(4)	1.61(2)	4.28(6)
Trowbridge shrew	*Sorex trowbridgii*	0.71(1)	0	0	0
Vagrant shrew	*Sorex vagrans*	20.00(28)	3.57(5)	3.22(4)	0.71(1)
Deer mouse	*Peromyscus maniculatus*	6.43(9)	2.14(3)	0	1.43(2)
California vole	*Microtus californicus*	13.57(19)	4.28(6)	0.81(1)	2.14(3)

Table 5. Amphibian, reptile and mammals species detected using cover boards (CB), sooted track plates (TP), and incidental wildlife observations (WO) in the four habitat areas.

Common Name	Scientific Name	Restricted/ restored	10-yr restricted/ unrestored	2-yr restricted/ unrestored	Unrestricted/ unrestored
Southern alligator lizard	*Elgaria multicarinata*	CB			
Brush rabbit	*Sylvilagus bachmani*	WO		WO	
Domestic dog	*Canis familiaris*		TP		
Red fox	*Vulpes vulpes*	WO			WO

A significant seasonal effect was detected in the number of individuals and the number of species captured per plot during the two trapping periods (X^2=40.67, df=1, p<0.0001; X^2=9.45, df=1, p=0.0021). A significantly higher number of individuals and species were detected during the 10-day trapping period in May, compared to February. An average of 8.93 ± 1.31 individuals and 3.37 ± 0.60 species was detected during the trapping period in May, compared to 1.59 ± 0.43 individuals and 1.37 ± 0.36 species during the trapping period in February.

A significant difference was also found between the numbers of individuals captured in the four habitat areas. An average of 14.31 ± 2.21 individuals was detected per plot in the restricted/restored area, 4.47 ± 1.06 individuals in the 10-year restricted/unrestored area, 1.25 ± 0.53 individuals in the 2-year restricted/unrestored area, and 2.5 ± 0.77 individuals in the unrestricted/unrestored area. More individuals were captured in the restricted/restored area compared to the restricted/restored (X^2=21.74, df=1, p<0.0001), 2-year restricted/restored (X^2=32.23, df=1, p<0.0001), and unrestricted/unrestored areas (X^2=30.54, df=1, p<0.0001). A significantly higher number of individuals were also captured in the 10-year restricted/unrestored area compared to the 2-year restricted/unrestored area (X^2=7.48, df=1, p=0.0063; Figure 5). However, there were no differences detected between the unrestricted/unrestored area compared to the 10-year and 2-year restricted/unrestored sites (X^2=2.55, df=1, p=0.11; X^2=1.89, df=1, p=0.169).

Figure 5. Vertebrate abundance (mean number of individuals ± SE) in four habitat areas; p<0.01. Treatments sharing the same lower-case letter are not significantly different.

The number of terrestrial vertebrate species captured was significantly different in the four habitat areas during the two trapping periods. An average of 4.76 ± 0.97 species was detected in the restricted/restored area, 2.72 ± 0.72 species per plot in the 10-year restricted/unrestored area, 0.91 ± 0.41 species in the 2-year restricted/unrestored area, and 1.81 ± 0.58 species in the unrestricted/unrestored area (Figure 6). More species were captured in the restricted/restored area compared to the unrestricted/unrestored area (X^2=6.8, df=1, p=0.0091) and the 2-year restricted/unrestored area (X^2=11.65, df=1, p=0.0006). A significantly higher number of species was captured in the 10-year restricted/unrestored area compared to the 2-year restricted/unrestored area (X^2=4.56, df=1, p=0.0327), but not compared to the unrestricted/unrestored area (X^2=0.99, df=1, p=0.3186). There was a trend towards a higher number of species in the restricted/restored area compared to the 10-year restricted/unrestored area (X^2=3.01, df=1, p=0.0825). There was not a significant interaction effect between the habitat area and the seasonal effects (X^2=0.69, df=1, p=0.4066).

Figure 6. Vertebrate species richness (mean number of species ± SE) in four habitat areas; p<0.01. Treatments sharing the same lower-case letter are not significantly different.

Cover boards and sooted-track plates: Cover boards and sooted-track plates had an extremely low rate of detection. No additional species were detected using these methods. A southern alligator lizard (*Elgaria multicarinata*) was detected on one occasion using cover boards in the restricted/restored area, accounting for a 0.63% detection rate. Domestic dogs (*Canis familiaris*) were detected on two occasions using sooted-track plates in the 10-year restricted/unrestored area, accounting for a 1.25% detection rate.

Incidental observations: In addition to the species identified with standard techniques, incidental wildlife observations detected two more vertebrate species, red fox (*Vulpes vulpes*) and brush rabbit (*Sylvilagus bachmani*). Red fox were observed on one occasion in August 2001 at the dog watering station, and on three occasions in May 2002 in the restricted/restored area. Red fox were observed digging around a pitfall trap on one occasion, sitting within 15 meters from a dozen people and dogs at the watering station on one occasion, and walking at the edge of the dunes near the ocean on two occasions. Brush rabbits were observed singly on five occasions, or in a pair on one occasion in May 2001, June 2001, and May 2002. On five out of six occasions, individual rabbits were observed in the restricted/restored area. On one occasion, an individual was observed at the edge of the 2-year restricted/unrestored and the restricted/restored areas.

Dog point count surveys and dog-wildlife interactions: During the monthly avian point count surveys, no dogs were recorded in the restricted/restored area, an average of 3.0 ± 2.0 dogs were recorded in the 10-year restricted/unrestored area, 1.25 ± 6.25 dogs were recorded in the 2-year restricted/unrestored area, and 5.13 ± 10.12 dogs were recorded in the unrestricted/unrestored area. No significant differences were found between the sites.

On four occasions, we directly witnessed dog-wildlife interactions. On the first occasion, a red fox was seen sitting less than 15 meters uphill from a group of six or more dogs. The fox's behavior remained unchanged while the dogs barked at close proximity. The dogs also appeared unaffected by the presence of the fox. Eventually, the fox receded into the brush. On the second occasion, a pocket gopher (*Thomomys bottae*) was observed chattering and baring its teeth in the direction of a dog and its owner. When we questioned the owner, he stated that his off-leash pet was chasing the animal. The owner stated that the gopher turned around and bit the dog on the nose when the gopher felt threatened. The gopher seemed unharmed and dug itself a new burrow within 15 minutes after the event occurred. On the third occasion, a dog was witnessed chasing a pocket gopher within the 10-year restricted/unrestored area. The dog was restrained and the gopher was not harmed. On the fourth occasion, a dog was witnessed chasing a pocket gopher within the 10-year restricted/unrestored area. The dog caught the gopher and consumed it.

Characterization of Vegetation

The vegetation data were used to estimate species diversity, cover class, and dominance of native and non-native species in the four habitat areas (Table 6). There was a significant difference in total species richness, including native and non-native species, between the four habitat areas ($p<0.05$). The highest total species richness was found in the restricted/restored area. There was a significant difference between the restricted/restored area compared to the 10-year restricted/unrestored, 2-year restricted/unrestored and unrestricted/unrestored areas ($t=4.38$, $df=29$, $p<0.01$; $t=2.46$, $df=29$, $p=0.02$; $t=2.33$, $df=29$, $p<0.01$). The restricted/restored area also exhibited the highest ratio of native species to non-native species compared to the three unrestored sites. The total species richness for the restricted/unrestored and unrestricted/unrestored sites was not significantly different.

Table 6. Vegetation characteristics found on four habitat types in Fort Funston, Golden Gate National Recreation Area. Mean values are followed by standard errors. Species richness is given in mean species per plot. Cover class values follow the scale 1=0-5, 2=5-10, 3=10-25, 4=25-50, 5=50-75, 6=75-100.

Habitat Area	**Species Richness**		**Cover Class**		**Annual Cover Class**	
	Native	Non-native	Native	Non-native	Native	Non-native
Restricted/restored	3.87±0.47	0.67±0.13	5.93±1.14	2.17±0.62	2.15±0.41	2.50±0.42
10-year restricted/unrestored	1.73±0.39	1.33±0.11	3.70±0.81	8.77±2.16	1.28±0.26	2.87±0.33
2-year restricted /unrestored	0.67±0.23	1.47±0.16	1.16±0.54	5.43±0.36	0.70±0.11	3.07±0.75
Unrestricted /unrestored	0.73±0.23	1.47±0.10	1.23±0.39	5.67±0.57	1.18±0.28	4.25±0.45

Similar results were found for cover of native vegetation. The highest cover was found in the restricted/restored area compared to the other three areas. There was a significant difference in native vegetation cover between the restricted/restored area, compared to the 10-year restricted/unrestored, 2-year restricted/unrestored, and unrestricted/unrestored areas ($t=6.14$, $df=29$, $p<0.01$; $t=4.22$, $df=29$, $p<0.01$; $t=6.71$, $df=29$, $p<0.01$). A significant difference was also found between the 10-year restricted/unrestored and 2-year restricted/unrestored areas ($t=2.10$, $df=29$, $p=0.04$), as well as the 10-year restricted/unrestored and unrestricted/unrestored areas ($t=2.73$, $p<0.01$). The cover of non-native vegetation exhibited an inverse trend. Non-native cover was significantly lower on the restricted/restored area than the 10-year restricted/unrestored, 2-year restricted/unrestored, and the unrestricted/unrestored areas ($t=-4.16$, $df=29$, $p<0.01$; $t=-2.94$, $df=29$, $p<0.01$; $t=-4.53$, $df=29$, $p<0.01$). No significant differences were found between the other areas.

A separate analysis was conducted for annual plants. The total cover of annual plant species was significantly higher in the unrestricted/unrestored area than in the 2-year restricted/unrestored, 10-year restricted/unrestored, and restricted/restored areas ($t=4.53$, $df=29$, $p<0.01$; $t=3.65$, $df=29$, $p<0.01$; $t=4.65$, $df=29$, $p<0.01$). No significant difference was found between the other areas.

DISCUSSION

It has been well documented that small fragments of native habitat can conserve biodiversity (Schwartz and van Mantgem 1997), although the sustainability of viable populations may be difficult in small fragments adjacent to urban areas. These fragments may be highly impacted by human disturbance, predators and parasites (Robinson et al. 1995), serving as ecological sinks for native species (Pulliam 1988). Habitat restoration projects are important for maintaining locally threatened plant and wildlife populations within highly fragmented, urban landscapes. It is also important to monitor restoration efforts to gauge progress towards project objectives. Analysis of wildlife richness and abundance at Fort Funston in the Golden Gate National Recreation Areas indicated significant between restored and unrestored sites.

The highest richness, as well as the greatest number of individuals, of terrestrial wildlife species was found in an area where active habitat restoration has occurred and where visitor use had been restricted. The number of individuals and the richness of species and the number of avian species were significantly higher in the restricted/restored area compared to the unrestricted/unrestored area. In addition, differences in species composition were noted between the four habitat areas. Two avian species were found exclusively in the unrestricted/unrestored area, while three avian species were found exclusively in the restricted/restored area. These results indicate that despite the mobility of avian species, variation in native plant dominance and richness may effect avian distributions on a local level. The response of terrestrial vertebrate species to variations in habitat was even more dramatic. The number of species of vertebrates, and the number of vertebrate individuals, in the restricted/restored area was more than twice as high as the 2-year restricted/unrestored and unrestricted/unrestored areas, and one-third greater than the restricted/unrestored area.

The variation in wildlife diversity and abundance between the four sites reflected differences in vegetation. The greatest differences were found between the restricted/restored area and the other three areas. The diversity of vegetation and the ratio of native to non-native plant species were highest in the restricted/restored area. The native community includes not only greater diversity of species, but also greater structural diversity. This was expected as active restoration involved the introduction of a wide variety of native species. Similar patterns emerged for the percent cover of native vegetation. The highest percent cover of native vegetation was found in the restricted/restored area with lower values in the other three habitat areas. However, a significant difference in native cover was also found between the 10-year restricted/unrestored area compared to the 2-year restricted/unrestored and the unrestricted/unrestored areas. Restricted use in this case appears to have facilitated an increase in native plant cover. However, because no other variable exhibited a similar trend, the effect needs to be tested further. The cover of non-native plant species exhibited the reverse trend. Non-native plant cover was lowest in the restricted/restored area, but there were no differences detected between the other three areas. The highest native to non-native percent cover ratio was found in the restricted/restored area. In contrast, the total percent cover of non-native and native annuals combined was found to be significantly higher in the unrestricted/unrestored area compared to the restricted/unrestored areas, suggesting that disturbance caused by visitor usage may facilitate the dominance of annual plants.

The data from this study indicate that active habitat restoration had a positive effect on the species richness of avian and terrestrial wildlife species, as well as the number of individuals of terrestrial wildlife species. However, the value of restricting visitor use in improving both vegetation and wildlife abundance and diversity was not as clear. The reason that there was little measurable difference in the variables tested between the restricted site and unrestricted site could be due a variety of reasons: (1). Fencing may have been inadequate in removing human disturbance. On many occasions, dogs and humans were observed walking inside the restricted/unrestored areas; (2).. In Fort Funston, there may have been inherent differences in the study areas before restoration efforts were implemented. Because the treatments were set up well before the study commenced, it is difficult to accurately assess the initial conditions; (3). In Fort Funston, the degree of human disturbance and habitat conditions may not be comparable to the impacts in previous studies where responses to fence exclosures did occur; (4). Restricting visitor use in the absence of active habitat restoration may not measurably improve species diversity and abundance.

In Fort Funston, survey methods detected two to three times more bird, amphibian, reptile, and mammal species in the restricted/restored habitat compared to the unrestricted/unrestored habitat. Species such as the California newt, Mourning Dove, Bewick's Wren, Bushtit, and trowbridge shrew were only detected in the 9.3-hectare, restricted/restored area. Similarly, these areas of higher species diversity also contained more nest parasites and nest predators. Species such as the Brown-headed Cowbird and the red fox were detected in the restricted/restored area but were absent in the unrestricted/unrestored area. Increased monitoring efforts may be required to better understand the relationship between habitat restoration and non-native wildlife species in urban environments. This information will enable land managers to more efficiently utilize the limited resources that are available for habitat restoration projects.

Recommended Monitoring Plan

For all future projects we recommend that monitoring begin prior to implementation. Collecting data before the inception of a project allows for comparisons between initial conditions and future conditions. Without this baseline data prior conditions must be ascertained from historic records, and cannot be compared statistically.

Wildlife monitoring: Variable circular plot point count, pitfall trap array, and incidental observation techniques were fairly comprehensive in detecting a variety of species in Fort Funston. We recommend conducting a wildlife monitoring program during the early part of the dry season (May-July), sampling vertebrates annually. This includes (1) point count surveys to be conducted one time each month for three months and (2) pitfall trap array surveys to be conducted during at least one 10-day trapping period.

Sooted-track plates were ineffective at detecting mid-sized mammals due to fog drip, wind and sun exposure in the coastal dune habitat. Therefore, we recommend exploring alternative methods such as sand track stations, camera traps, or evening spotlight surveys to survey foxes, skunks, and other mid-sized mammals.

It is also important to understand the effects of restoration efforts on the fitness of individual species. Otherwise, restored habitats may serve as sinks for locally threatened populations (Pulliam 1988). For example, native dune vegetation may attract breeding bird species as well as nest parasites that may ultimately decimate a species' reproductive success. We recommend initiating a pilot project to monitor the productivity and survivorship of breeding birds in Fort Funston.

Non-native red foxes are well-known predators of native species, including birds and other small prey (Risbey et al. 1999, Harding et al. 1998), especially in areas where other top carnivores are absent (Soule et al. 1988). Land managers should immediately address this issue by considering alternative management strategies such as habitat modification, behavioral modification, and direct removal techniques (U.S. Fish and Wildlife Service 1990).

Vegetation monitoring: We suggest a re-sampling of all habitat areas on an annual basis. Identical methods should be used to facilitate statistical analysis between years. Sample plots should be re-randomized with each annual sampling. This approach will increase the variation from year to year, but will result in a more inclusive analysis of the site. It is also essential that the same number of plots be assigned to each treatment area with each sampling, and that the plot size and shape remain the same. The sampling should also be limited to a single season. It is suggested that the peak of annual flowering (April-June) be used as the trigger for commencement of sampling.

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LITERATURE CITED

Alvarez, M.E. and Cushman, J.H. 1997. Influence of an invasive plant on species richness and composition of three coastal plant communities. Supplement to the Bulletin of the Ecological Society of America. 1997 Annual Meeting 10-14 August 1997, Albuquerque, New Mexico. Changing Ecosystems: Natural and Human Influences. Abstracts, p. 46.

Baker, A. 1999. Crissy Field Dune Vegetation Monitoring 1999. Golden Gate National Park Association, San Francisco, California.

Barrett, R. H. 1983. Smoked aluminum track plots for determining furbearer distributions and relative abundance. Calif. Fish & Game. 69:188-190.

Block, W.M., A.B. Franklin, J.P. Ward, Jr., J.L. Ganey, and G.C. White. 2001. Design and implementation of monitoring studies to evaluate the success of ecological restoration on wildlife. Restoration Ecology 9(3):293-303.

Bolander, H.N. 1863. Enumeration of shrubs and trees growing in the vicinity of the mouth of San Francisco Bay. California Academy of Sciences Proceedings 2: 78-84.

Brandegee, K. 1892. Catalogue of the flowering plants and ferns growing spontaneously in the city of San Francisco. Zoe 2: 334-383.

Bury, R. B. and Raphael, M. G. 1983. Inventory methods for amphibians and reptiles. pp. 416-419. *In*: J. F. Bell & T. Attebury (eds.). Proceedings of an International Conference, renewable resource inventories for monitoring changes in trends. August 15-19, 1983. Corvallis, OR. SAF 83-14.

Cooper, W.S. 1967. Coastal dunes of California. Geological Society of America Memoir 104. Denver, Colorado.

Corn, P.S. and R.B. Bury 1990. Sampling methods for terrestrial amphibians and reptiles. U.S. Department of Agriculture, U.S. Forest Service, General Technical Report PNW-GTR-256.

Craig, A. 1971. Survey of California least tern nesting sites. California Department of Fish and Game, Sacramento, California. Proj. W-54-R-4.

Davis, D. 1982. Handbook of census methods for terrestrial vertebrates. CRC Press, Inc. Boca Raton, FL. pp. 397.

DeGraff, R. M. and M. Yamasaki. 1992. A nondestructive technique to monitor the relative abundance of terrestrial salamanders. Wildl. Soc. Bull. 20:260-264.

Edwards, O. M. 1978. Vegetation disturbance by natural factors and visitor impact in the alpine zone of Mount Rainier National Park: implications for management. In: Recreational Impact on Wildlands, Conference Proceedings. U.S.F.S. No. R-6-001-1979.

Gaar, G. 1999. Private collection: historic San Francisco photography. Neighborhood Parks Council, San Francisco.

Grant, B. W., A.D. Tucker, J.E. Lovich, A.M. Mills, P.M. Dixon, and J.W. Gibbons. 1992. The use of coverboards in estimating patterns of reptile and amphibian biodiversity. pp. 379-403. *In*: D. R. McCullough & R. H. Barrett, eds. Wildlife 2001:Populations. Elsevier Applied Science, New York, NY. pp. 1163.

Grove, T., C. Lester, and R. Brooke. 2000. Oceano Dunes State Vehicular Recreation Area (ODSVRA): informational briefing on status of coastal commission review of carrying capacity study required by conditions of permit 4-82-300, issued to California Department of Parks and Recreation, to determine appropriate limits on day and overnight use. Central Coast District Office, California Coastal Commission, Santa Cruz, California. (June 13, 2000).

Harding, E.K., D.F. Doak, J. Albertson, and J.E. Takekawa. 1998. Predator management in San Francisco Bay wetlands: past trends and future strategies. Final report. U.S. Fish and Wildlife Service, Division of Ecological Services, Sacramento, CA.

Hatch, D. A. 1996. Western snowy plover (a federally threatened species) wintering population and interaction with human activity on Ocean Beach, San Francisco, Golden Gate National Recreation Area, 1988-1996. Unpublished report, National

Park Service, Golden Gate National Recreation Area, San Francisco, California. 29pp.
Howell, J.T., P.H. Raven, and P. Rubtzoff. 1958. A Flora of San Francisco, California. Wasmann Journal of Biology. v. 16, University of San Francisco, San Francisco.
Kaufeldt, C.E. 1954. Observations of San Francisco's last sand dune, with notes on its flora and insect fauna. The Wasson Journal of Biology 12: 293-336.
Lafferty, K. D. 2000. Status, trends, and conservation of the western snowy plover with a focus on the Devereux Slough population at Coal Oil Point Reserve, Santa Barbara County, California. Museum of Systematics and Ecology Environmental Report No. 15, University of California, Santa Barbara.
Marzluff, J.M. and K. Ewing. 2001. Restoration of fragmented landscapes for the conservation of birds: a general framework and specific recommendations for urbanizing landscapes. Restoration Ecology 9(3):280-292.
Massey, B. W. 1972. Breeding biology of the California least tern. M. S. Thesis, California State University, Long Beach, California. 101pp.
McCullagh, P. and J.A. Nelder. 1989. Generalized Linear Models, 2nd Edition. Chapman and Hall, London.
Morrison, M.L., T.A. Scott, and T. Tennant. 1994. Wildlife-habitat restoration in an urban park in southern California. Restoration Ecology 2(1):17-30.
Page, G. W. 1990. Nesting success of snowy plovers in central coastal California in 1989 and 1990. Report of the Point Reyes Bird Observatory, Stinson Beach, California. 13 pp.
Pickart, A. J. and J.O. Sawyer. 1998. Ecology and Restoration of Northern California Coastal Dunes. California Native Plant Society, Sacramento, California.
Pulliam, H.R. 1988. Sources, sinks, and population regulation. American Naturalist 132:652-661.
Rae, A. 2002. Human impact on the Dorset coastline – a DME. GeoFile Online 420:1-4.
Ralph, C. J., G.R. Geupel, P. Pyle, T.E. Martin, and D.F. DeSante. 1993. Handbook of field methods for monitoring landbirds. USDA Forest Service General Technical Report. PSW-GTR-144.
Ramaley, F. 1918. Notes on dune vegetation at San Francisco. Plant World 21: 191-201.
Risbey, D.A., M.C. Calver, and J. Short. 1999. The impact of cats and foxes on the small vertebrate fauna of Heirisson Prong, Western Australia. I. Exploring potential impact using diet analysis. Wildlife Research 26:621-630.
Robinson, S.K., F.R. Thompson, III, T.M. Donovan, D.R. Whitehead, and J. Faaborg. 1995. Regional forest fragmentation and the nesting success of migratory birds. Science 267:1987-1990.
Sauer, J.R., J.E. Hines, and J. Fallon. 2001. The North American Breeding Bird Survey, Results and Analysis 1966-2000. USGS Web Report.
Saul, S. M. 1982. Clam diggers and snowy plovers. Washington Wildlife 32(1):28-30.
SAS. 1999. SAS Institute. Cary, NC.
Schwartz, M.W. and P.J. van Mantgem. 1997. Conservation in Highly Fragmented Landscapes. Chapman and Hall, New York, NY. pp. 1-448.
Sime, C. A. 1999. Domestic dogs in wildlife habitats. pp. 8.1-8.17. In:Joslin, G. &

Youmans, H. coordinators. Effects of recreation on Rocky Mountain wildlife: a review for Montana. Committee on Effects of Recreation on Wildlife, Montana Chapter of The Wildlife Society.

Soule, M.E., D.T. Bolger, A.C. Alberts, J. Wright, M. Sorice, and S. Hill. 1988. Reconstructed dynamics of rapid extinctions of chaparral-requiring birds in urban habitat islands. Conservation Biology 2:75-92.

Unocal 2002. Guadalupe Restoration Project: Guadalupe Oil Field. Address to the California SER Dune Guild, held in Guadalupe, California, September 28, 2002.

U.S. Fish and Wildlife Service. 1990. Final Environmental Impact Statement: Endangered, Species Management and Protection Plan, Naval Weapons Station – Seal Beach National Wildlife Refuge. U.S. Fish and Wildlife Service, Portland, OR and US Navy, Seal Beach, CA.

U.S. Fish and Wildlife Service. 2001. Western Snowy Plover (Charadrius alexandrinus nivosus) Pacific Coast Population Draft Recovery Plan. Region 1, U.S. Fish and Wildlife Service, Portland, Oregon. 228 pp.

APPENDIX 1

Bird monitoring plots: variable circular plot point count stations and UTM coordinates (WGS 84)

Plot	Easting	Northing
1	543866	4174375
2	543785	4174561
3	543670	4174956
4	543601	4175169
5	543727	4175342
6	543640	4175424

APPENDIX 2
Bird monitoring plots: area search locations

APPENDIX 3

Pitfall trap array locations, UTM coordinates (WGS 84)

Plot	Easting	Northing	Arm1	Arm2	Arm3
1	543819	4174453	244	355	132
2	543761	4174543	322	99	196
3	543684	4174945	306	74	188
4	543682	4175013	310	60	212
5	543633	4175079	22	148	259
6	543564	4175310	8	133	232
7	543726	4175316	18	125	260
8	543633	4175435	287	28	178

APPENDIX 4

Location of Vegetation Sample Plots

	Plot	GPS (deg)		Site	Plot	GPS (deg)		Site	Plot	GPS (deg)		Site	Plot	GPS (deg)	
1	1	N37 43' 39.2"	W122 30' 24.0"	2	1	N37 43' 28.7"	W122 30' 18.5"	3	1	N37 43' 17.9"	W122 30' 14.9"	4	1	N37 42' 53.2"	W122 30' 09.5"
1	2	N37 43' 39.2"	W122 30' 23.2"	2	2	N37 43' 26.6"	W122 30' 20.7"	3	2	N37 43' 17.7"	W122 30' 15.9"	4	2	N37 42' 53.5"	W122 30' 09.7"
1	3	N37 43' 38.6"	W122 30' 23.8"	2	3	N37 43' 26.4"	W122 30' 18.0"	3	3	N37 43' 17.3"	W122 30' 15.4"	4	3	N37 42' 52.9"	W122 30' 10.0"
1	4	N37 43' 38.1"	W122 30' 23.5"	2	4	N37 43' 25.6"	W122 30' 19.3"	3	4	N37 43' 16.8"	W122 30' 15.9"	4	4	N37 42' 54.2"	W122 30' 10.6"
1	5	N37 43' 37.7"	W122 30' 23.4"	2	5	N37 43' 25.6"	W122 30' 19.9"	3	5	N37 43' 16.8"	W122 30' 18.6"	4	5	N37 42' 54.7"	W122 30' 09.1"
1	6	N37 43' 37.2"	W122 30' 23.2"	2	6	N37 43' 26.2"	W122 30' 19.9"	3	6	N37 43' 16.3"	W122 30' 15.9"	4	6	N37 42' 54.8"	W122 30' 08.4"
1	7	N37 43' 36.7"	W122 30' 23.3"	2	7	N37 43' 25.9"	W122 30' 20.6"	3	7	N37 43' 16.3"	W122 30' 15.4"	4	7	N37 42' 55.0"	W122 30' 08.1"
1	8	N37 43' 36.7"	W122 30' 22.6"	2	8	N37 43' 25.0"	W122 30' 20.8"	3	8	N37 43' 16.3"	W122 30' 14.8"	4	8	N37 42' 55.6"	W122 30' 08.5"
1	9	N37 43' 36.3"	W122 30' 23.3"	2	9	N37 43' 24.8"	W122 30' 19.3"	3	9	N37 43' 16.3"	W122 30' 16.5"	4	9	N37 42' 55.0"	W122 30' 08.7"
1	10	N37 43' 35.3"	W122 30' 23.2"	2	10	N37 43' 25.4"	W122 30' 18.8"	3	10	N37 43' 15.8"	W122 30' 16.7"	4	10	N37 42' 55.1"	W122 30' 08.9"
1	11	N37 43' 35.3"	W122 30' 22.6"	2	11	N37 43' 23.8"	W122 30' 19.4"	3	11	N37 43' 15.8"	W122 30' 16.1"	4	11	N37 42' 56.9"	W122 30' 11.8"
1	12	N37 43' 35.1"	W122 30' 21.9"	2	12	N37 43' 23.6"	W122 30' 18.7"	3	12	N37 43' 15.2"	W122 30' 16.1"	4	12	N37 42' 57.9"	W122 30' 12.1"
1	13	N37 43' 34.6"	W122 30' 21.8"	2	13	N37 43' 24.0"	W122 30' 19.9"	3	13	N37 43' 15.3"	W122 30' 15.5"	4	13	N37 42' 56.3"	W122 30' 11.4"
1	14	N37 43' 36.7"	W122 30' 22.1"	2	14	N37 43' 23.3"	W122 30' 19.6"	3	14	N37 43' 14.7"	W122 30' 18.6"	4	14	N37 42' 57.2"	W122 30' 08.1"
1	15	N37 43' 37.3'	W122 30' 22.2"	2	15	N37 43' 22.8"	W122 30' 19.4"	3	15	N37 43' 14.2"	W122 30' 16.3"	4	15	N37 42' 57.9"	W122 30' 07.0"
1	16	N37 43' 34.0"	W122 30' 19.8"	2	16	N37 43' 23.6"	W122 30' 19.2"	3	16	N37 43' 14.0"	W122 30' 17.0"	4	16	N37 42' 58.3"	W122 30' 07.8"
1	17	N37 43' 33.4"	W122 30' 19.4"	2	17	N37 43' 22.5"	W122 30' 18.2"	3	17	N37 43' 13.3"	W122 30' 17.0"	4	17	N37 42' 58.3"	W122 30' 08.4"
1	18	N37 43' 32.8"	W122 30' 20.8"	2	18	N37 43' 22.4"	W122 30' 17.7"	3	18	N37 43' 13.4"	W122 30' 17.7"	4	18	N37 42' 58.7"	W122 30' 08.9"
1	19	N37 43' 32.2"	W122 30' 20.9"	2	19	N37 43' 22.0"	W122 30' 19.8"	3	19	N37 43' 12.9"	W122 30' 17.1"	4	19	N37 42' 59.1"	W122 30' 08.8"
1	20	N37 43' 29.7"	W122 30' 20.8"	2	20	N37 43' 21.3"	W122 30' 18.5"	3	20	N37 43' 12.4"	W122 30' 17.1"	4	20	N37 42' 59.3"	W122 30' 07.5"
1	21	N37 43' 30.4"	W122 30' 18.4"	2	21	N37 43' 21.4"	W122 30' 20.0"	3	21	N37 43' 12.4"	W122 30' 17.7"	4	21	N37 42' 59.8"	W122 30' 07.3"
1	22	N37 43' 29.5"	W122 30' 16.8"	2	22	N37 43' 21.0"	W122 30' 18.0"	3	22	N37 43' 12.0"	W122 30' 17.5"	4	22	N37 43' 00.1"	W122 30' 08.5"
1	23	N37 43' 29.1"	W122 30' 15.9"	2	23	N37 43' 20.5"	W122 30' 18.2"	3	23	N37 43' 12.0"	W122 30' 16.9"	4	23	N37 43' 00.1"	W122 30' 09.1"
1	24	N37 43' 28.6"	W122 30' 16.5"	2	24	N37 43' 20.2"	W122 30' 17.9"	3	24	N37 43' 10.8"	W122 30' 16.1"	4	24	N37 42' 59.7"	W122 30' 09.9"
1	25	N37 43' 27.6"	W122 30' 15.4"	2	25	N37 43' 20.4"	W122 30' 19.8"	3	25	N37 43' 11.0"	W122 30' 15.8"	4	25	N37 43' 00.1"	W122 30' 10.2"
1	26	N37 43' 27.8"	W122 30' 15.4"	2	26	N37 43' 21.3"	W122 30' 21.0"	3	26	N37 43' 10.5"	W122 30' 14.3"	4	26	N37 42' 59.7"	W122 30' 10.6"
1	27	N37 43' 26.5"	W122 30' 15.4"	2	27	N37 43' 20.1"	W122 30' 19.4"	3	27	N37 43' 09.7"	W122 30' 15.0"	4	27	N37 42' 59.9"	W122 30' 10.8"
1	28	N37 43' 26.1"	W122 30' 13.3"	2	28	N37 43' 19.6"	W122 30' 18.7"	3	28	N37 43' 10.3"	W122 30' 15.4"	4	28	N37 43' 00.6"	W122 30' 09.2"
1	29	N37 43' 26.9"	W122 30' 13.4"	2	29	N37 43' 19.5"	W122 30' 17.4"	3	29	N37 43' 09.7"	W122 30' 13.6"	4	29	N37 43' 00.8"	W122 30' 08.4"
1	30	N37 43' 27.8"	W122 30' 12.6"	2	30	N37 43' 19.7"	W122 30' 16.9"	3	30	N37 43' 09.1"	W122 30' 15.9"	4	30	N37 43' 01.5"	W122 30' 08.6"